CLAIMS:

1. A hydraulically operated braking system comprising:

a brake operating member (10) operable by an operator;

a master cylinder (12; 300: 500; 600) including a pressurizing piston (34; 322, 324; 504, 506) operatively connected to said brake operating member and partially defining a pressurizing chamber (30, 32; 302, 304; 508, 510), said pressurizing piston being moved by said brake operating member to pressurize a fluid in said pressurizing chamber;

a brake cylinder (22-28) actuated by the pressurized fluid received from said master cylinder; and

an assisting device (81; 260-272; 109; 538; 612) for applying to said pressurizing piston an assisting drive force which is different than a primary drive force to be applied to said pressurizing piston on the basis of a brake operating force acting on said brake operating member, said assisting device being electrically controllable to control said assisting drive force.

2. A hydraulically operated braking system according to claim 1, wherein said assisting device includes an assisting drive force control device (109; 538; 612) electrically operable to control said assisting drive force on the basis of at least one of a brake operating condition quantity

indicative of an operating condition of said brake operating member and a vehicle running condition quantity indicative of a running condition of an automotive vehicle having a wheel (14-20) which is braked by said brake cylinder (22-28).

3. A hydraulically operated braking system according to claim 1 or 2, wherein said assisting device comprises:

an assisting cylinder (78; 12, 224; 300, 360; 500, 512; 600, 512) including an assisting piston (92; 220; 322; 504) operatively connected to said pressurizing piston, said assisting cylinder having an assisting pressure chamber (100; 224; 360; 512) which is partially defined by said assisting piston;

a high-pressure source (70, 72);

a reservoir (76);

a solenoid-operated pressure control valve device (82) connected to said high-pressure source, said reservoir and said assisting pressure chamber, for selectively supplying the fluid from said high-pressure source to said assisting pressure chamber and returning the fluid from said assisting pressure chamber to said reservoir; and

a control valve control device (80) for controlling said solenoid-operated pressure control valve device to control a pressure of the fluid in said assisting pressure chamber.

4. A hydraulically operated braking system according to claim 1 or 2, wherein said assisting device comprises:

an assisting rod (260) operatively connected to said brake operating member;

an electrically operated actuator (262, 264) for applying an electrically generated drive force to said assisting rod; and

an actuator control device (270, 272) for controlling said actuator to control said electrically generated drive force for controlling said assisting drive force to be applied to said pressurizing piston.

5. A hydraulically operated braking system according to claim 1 or 2, further comprising an emergency closure valve (560) disposed between said assisting pressure chamber (512) and said solenoid-operated pressure control valve device (82) and which is normally placed in an open state for fluid connecting said assisting pressure chamber and said solenoid-operated pressure control valve device to each other, said emergency closure valve being brought to a closed state for disconnecting said assisting pressure chamber and said solenoid-operated pressure control valve device from each other, in the event of an abnormality of said solenoid-operated pressure control valve device.

6. A hydraulically operated braking system according to any one of claims 3-5, further comprising an emergency

high-pressure source communicating device (562; 616) for connecting said assisting pressure chamber (512) and said high-pressure source (70, 72) while by-passing said solenoid-operated pressure control valve device (82), in the event of an abnormality of said solenoid-operated pressure control valve device.

7. A hydraulically operated braking system according to claim 6, wherein said emergency high-pressure source communicating device includes (616) a pilot-operated pressure control valve (614) which is connected to said assisting pressure chamber (512), said high-pressure source (70, 72) and said reservoir (76) and which is operated in response to the fluid pressure in said pressurizing chamber (508) of said master cylinder (600) received as a pilot pressure, so as to control the fluid pressure received from said high-pressure source depending upon said pilot pressure, and apply the controlled fluid pressure to said assisting pressure chamber.

8. A hydraulically operated braking system according to claim 7, wherein said pilot-operated pressure control valve is provided in a by-pass passage (618) which connects said assisting pressure chamber and said high-pressure source while by-passing said solenoid-operated pressure control valve device, and said emergency high-pressure source communicating device (616) further includes a

higher-pressure applying device (615) connected to said by-pass passage, said solenoid-operated pressure control valve device and said assisting pressure chamber, said higher-pressure applying device being operated to apply a higher one of the fluid pressures received from said solenoid-operated pressure control valve device and said pilot-operated pressure control valve.

9. A hydraulically operated braking system according to claim 3, wherein said master cylinder (12) and said assisting cylinder (78) has respective separate cylinder housings, and said assisting piston (92) is operatively connected to said pressurizing piston (34) trough said brake operating member (10), and wherein pressure-receiving surface areas of said assisting and pressurizing pistons and distances between a fulcrum (96) of said brake operating member and points of connection of said assisting and pressurizing pistons to said brake operating member are determined such that a product of said pressure-receiving surface area of said assisting piston and said distance between said fulcrum and said point of connection of said assisting piston is smaller than a product of said pressure-receiving surface area of said pressurizing piston and said distance between said fulcrum and said point of connection of said pressurizing piston, said braking system further comprising an emergency fluid communicating device (80, 108; 80, 242, 244) disposed between said assisting

pressure chamber (100) and said pressurizing chamber (30), said emergency fluid communicating device being placed in a closed state disconnecting said assisting pressure chamber and said pressurizing chamber from each other during an operation of the braking system when said assisting device (81) is normally operable, and brought to an open state for fluid communication between said assisting pressure chamber and said pressurizing chamber in the event of occurrence of an abnormality of said assisting device during the operation of the braking system.

10. A hydraulically operated braking system according to any one of claims 3 and 5-8, wherein said master cylinder (12;, 300; 500; 600) and said assisting cylinder (300, 360; 500, 512; 500, 512) are disposed in series with each other, and said assisting piston (322; 504) has a pressure-receiving surface area smaller than that of said pressurizing piston (324; 504, 506), said braking system further comprising an emergency communicating device (372, 374, 382, 384; 542, 546, 547; 610, 615) disposed between said assisting pressure chamber (360; 512) and said pressurizing chamber (302, 304; 508, 510), said emergency fluid communicating device being placed in a closed state disconnecting said assisting pressure chamber and said pressurizing chamber from each other during an operation of the braking system when said assisting device (109; 538; 612) is normally operable, and brought to an open state for

fluid communication between said assisting pressure chamber and said pressuring chamber in the event of occurrence of an abnormality of said assisting device during the operation of the braking system.

11. A hydraulically operated braking system according to claim 9 or 10, wherein said emergency fluid communicating device (610, 615) includes a mechanically operated switch valve (615) which is switched from a closed state for disconnecting said assisting pressure chamber (512) and said pressurizing chamber (508), to an open state for fluid communication between said assisting pressure chamber and said pressurizing chamber when the fluid pressure in said high-pressure source (70, 72) is lowered below a predetermined lower limit.

12. A hydraulically operated braking system according to claim 9 or 10, wherein said emergency fluid communicating device includes an electrically operated switch valve (108; 242; 372, 382; 542, 546; 610) which is switched from a closed state for disconnecting said assisting pressure chamber and said pressurizing chamber, to an open state for fluid communication between said assisting pressure chamber and said pressurizing chamber in the even of occurrence of an abnormality of said assisting device (108; 538; 612).

13. A hydraulically operated braking system according to any one of claims 9-12, wherein said emergency fluid communicating device is brought to said open state in the event of occurrence of said abnormality of said assisting device, if the fluid pressure in said pressurizing chamber is higher than the fluid pressure in said assisting pressure chamber by more than a predetermined amount.

14. A hydraulically operated braking system according to any one of claims 9-13, wherein said emergency fluid communicating device includes (a) a fluid passage (240; 380; 528; 608) connecting said assisting pressure chamber and said pressurizing chamber, (b) a switch valve (242; 372, 382; 542) which is disposed in said fluid passage and which is switched from a closed state disconnecting said assisting pressure chamber and said pressurizing chamber, to an open state for communication between said assisting pressure chamber and said pressurizing chamber, in the event of said abnormality of said assisting device, and (c) a differential shut-off valve (248; 376, 388; 548) which is disposed in said fluid passage in series with said switch valve and which permits a flow of the fluid from said pressurizing chamber towards said assisting pressure chamber when the fluid pressure in said pressurizing chamber has become higher than the fluid pressure in said assisting pressure chamber by more than said predetermined amount.

15. A hydraulically operated braking system according to any one of claims 9, 10, 12 and 13, wherein said emergency fluid communicating device includes an electrically operated switch valve (108; 610) which is disposed between said assisting pressure chamber and said pressurizing chamber and which is switchable between a closed state disconnecting said assisting pressure chamber and said pressurizing chamber and an open state for communication between said assisting pressure chamber and said pressurizing chamber, and a switch valve control means (80) for switching said electrically operated switch valve from said closed state to said open state when said assisting device is not normally operable and when the fluid pressure in said pressurizing chamber is higher than the fluid pressure in said assisting pressure chamber by more than said predetermined amount.

16. A hydraulically operated braking system according to any one of claims 3, 5-8 and 13-15, further comprising an emergency reservoir communicating device (210) disposed between said assisting pressure chamber (100; 224) and said reservoir (76), said emergency reservoir communicating device being placed in a closed state disconnecting said assisting pressure chamber and said reservoir from each other during an operation of the braking system when said assisting device is normally operable, and brought to an open state for fluid communication between said assisting pressure chamber and said reservoir in the event of

occurrence of an abnormality of said assisting device during the operation of the braking system.

17. A hydraulically operated braking system according to any one of claims 1-16, further comprising;

a master reservoir (76);

a fluid passage (398, 399; 532) for fluid communication between said master reservoir and said pressurizing chamber (302, 304; 508) of said master cylinder (300; 500), irrespective of a position of said pressurizing piston (322, 324; 504, 506); and

a check valve (402, 404; 533) disposed in said fluid passage, said check valve inhibiting a flow of the fluid from said pressurizing chamber towards said master reservoir and allowing a flow of the fluid from said master reservoir towards said pressurizing chamber.

18. A hydraulically operated braking system according to claim 17, wherein said master cylinder (300; 500) includes a cylinder housing (320; 502) having a port (406, 407; 530) connected to said fluid passage (398, 399; 532) and communicating with said pressurizing chamber (302; 304; 508), said master cylinder further including a device (334, 336, 337) for preventing said port from being closed by said pressurizing piston.

19. A hydraulically operated braking system according to any one of claims 1-18, wherein said master cylinder (300) includes (a) a first pressurizing piston (322) operatively connected to said brake operating member (10) partially defining a first pressurizing chamber (302) whose volume decreases as said first pressurizing piston is moved, (b) a second pressurizing piston (324) which said partially defines said first pressurizing chamber and a second pressurizing chamber (304) in front of said first pressurizing chamber, so as to separate said first and second pressurizing chambers from each other, and which is movable relative to said first pressurizing piston, (c) a second pressurizing chamber pressurizing device (81, 109) for pressurizing the fluid in said second pressurizing chamber by supplying a pressurized fluid from a pressure source (70, 72) external to said master cylinder, into said second pressurizing chamber, and (d) a volume reduction preventing device (346, 347) for permitting the volume of said first pressurizing chamber to be increased as said first pressurizing piston is advanced from an original position thereof while said second pressurizing piston is placed in an original position thereof, and for preventing the volume of the first pressurizing chamber from being reduced when the fluid pressure in said second pressurizing chamber is increased by said second pressurizing chamber pressurizing device while said second pressuring piston is placed in said original position.

20. A hydraulically operated braking system according to claim 19, wherein said original position of said second pressurizing piston (324) is a fully retracted position thereof, and said volume reduction preventing device is a stopper device (346, 347) for preventing a movement of said second pressurizing piston from said fully retracted position in a direction opposite to a direction of an advancing movement of said second pressurizing piston.

21. A hydraulically operated braking system according to claim 19 or 20, wherein said second pressurizing piston (324) includes a partition portion (330) for dividing an interior of a cylinder housing (320) of said master cylinder (300) into said first and second pressurizing chambers (302, 304), and a cylindrical portion (332) disposed on one side of said partition portion which is on the side of said first pressurizing piston (322), said original position of said second pressurizing piston (324) being defined by an abutting contact of a rear open end face (346) of said cylindrical portion with a rear end face (347) of said cylinder housing, said stopper device including said rear open end face of said cylindrical portion and said rear end face of said cylinder housing, and wherein said first pressurizing piston (322) is slidably fitted in said cylindrical portion of said second pressurizing piston.

22. A hydraulically operated braking system according to claim 21, wherein said first pressuring chamber (302) includes an inner fluid chamber (348) formed within said cylindrical portion (332) of said second pressurizing piston (324) and in front of said first pressurizing piston (322), and an outer annular fluid chamber (344) formed between an outer circumferential surface of said second pressurizing piston and an inner circumferential surface of said cylinder housing (320), said cylindrical portion having a communication passage (350) for fluid communication between said inner fluid chamber and said outer annular fluid chamber.

23. A hydraulically operated braking system according to claim 22, wherein said outer annular fluid chamber (344) has a volume which is reduced as said second pressuring piston is advanced, and said communication passage (350) functions as a fluid flow restrictor for restricting a flow of the fluid between said inner fluid chamber and said outer annular fluid chamber.

24. A hydraulically operated braking system according to any one of claims 19-23, wherein said second pressurizing chamber (304) is connected to a wheel brake cylinder (22, 24) as said brake cylinder for braking a drive wheel of an automotive vehicle, said braking system further comprising a solenoid-operated shut-off valve (382) which is disposed

between said second pressurizing chamber pressurizing device (81, 109) and said second pressurizing chamber and which has an open position for fluid communication between said second pressurizing chamber pressurizing device and said second pressurizing chamber, and a closed position for disconnecting said second pressurizing chamber pressuring device and said second pressurizing chamber from each other, and a drive wheel braking pressure control device (80) for controlling the fluid pressure in said drive wheel brake cylinder while said solenoid-operated shut-off valve is held in said open state.

25. A hydraulically operated braking system according to any one of claims 1-24, further comprising a brake operating force estimating device (392, 394, 80) for estimating an operating force acting on said brake operating member (10), on the basis of the fluid pressure in said pressurizing chamber (302, 304, 508, 510) and said assisting drive force produced by said assisting device (81, 109; 81, 538; 81, 612).

26. A hydraulically operated braking system according to any one of claims 1-25, wherein said master cylinder (12) includes a cylinder housing (90) which cooperates with said pressurizing piston (34) to define said pressuring chamber (30, 32), said braking system further comprising a master cylinder characteristic control device (128; 266, 268-270,

274) for controlling an amount of the fluid in said pressurizing chamber (30) of said master cylinder (12), to thereby control a relationship between a position of said pressurizing piston (34) relative to said cylinder housing and the fluid pressure in said pressurizing chamber, for controlling a fluid pressurizing characteristic of said master cylinder.

27. A hydraulically operated braking system according to claim 26, wherein said master cylinder characteristic control device comprises:

a cylinder housing (110; 172);

a volume-changing piston (114; 174; 266) received in said cylinder housing of said master cylinder characteristic control device such that said volume-changing piston is movable relative to said cylinder housing of said master cylinder characteristic control device;

said volume-changing piston cooperating with said cylinder housing of said master cylinder characteristic control device to define a variable-volume chamber (116, 188) communicating with said pressurizing chamber; and

a fluid amount control device (70, 72, 80, 122, 124; 268-270, 274) for controlling a relative position of said volume-changing piston and said cylinder housing of said master cylinder characteristic control device, to control a volume of said variable-volume chamber, for

thereby controlling the amount of the fluid in said pressurizing chamber.

28. A hydraulically operated braking system according to claim 27, wherein said fluid amount control device includes a master cylinder pressurizing control means (70, 72, 80, 122, 124; 268-270, 274) for controlling the amount of the fluid in said pressurizing chamber, on the basis of an operating stroke of said pressurizing piston and according to a predetermined rule.

29. A hydraulically operated braking system according to any one of claims 26-28, wherein said master cylinder characteristic control device has a variable-volume chamber (116; 188) connected to a braking fluid chamber in said brake cylinder (22, 24) and said pressurizing chamber (30) of said master cylinder, and includes a fluid amount control device (70, 72, 80, 122, 124; 268-270, 274) for controlling a volume of said variable-volume chamber to control the amount of the fluid in said pressurizing chamber, said braking system further comprising an emergency master cylinder disconnecting device (62, 80) disposed between said variable-volume chamber and said pressurizing chamber, said emergency master cylinder disconnecting device being normally placed in an open state for fluid communication between said variable-volume chamber and said pressurizing chamber, and brought to a closed state for disconnecting

said variable-volume chamber and said pressurizing chamber from each other in the event of an abnormality of said assisting device (81; 260, 262, 264, 270, 272).

30. A hydraulically operated braking system comprising:

a brake operating member (10) operable by an operator;

a master cylinder (12) including a cylinder housing (90) and a pressurizing piston (34) operatively connected to said brake operating member and cooperating with said cylinder housing to define a pressurizing chamber (30, 32), said pressurizing piston being moved by said brake operating member to pressurize a fluid in said pressurizing chamber;

a brake cylinder (22-28) actuated by the pressurized fluid received from said master cylinder; and

a master cylinder characteristic control device (128; 266, 268-270, 274) for controlling an amount of the fluid in said pressurizing chamber (30) of said master cylinder, to thereby control a relationship between a position of said pressurizing piston relative to said cylinder housing and the fluid pressure in said pressurizing chamber, for controlling a fluid pressurizing characteristic of said master cylinder.